Selective Catalytic / Non-Catalytic Reduction Conference

Ammonia Slip and Increased SO_3 from SCR: Balancing Air Heater Deposits, Ammonia in Effluent Discharge, and SO_3 Plume

Presented by:
Thomas Wright
Parsons Energy & Chemicals Group
Chattanooga, Tennessee
May 16, 2002

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Agenda

- Introduction
- Formation and fate of ammonia
- Formation and fate of SO_3
- Air heater deposits
- Ammonia in effluent discharge
- SO_3 mitigation
- Balancing ammonia slip and SO_3
- Conclusions
- Recommendations

Introduction

- SCR produces
  - Ammonia (NH_3) slip
  - Increased sulfur trioxide (SO_3)
- Impacts on coal-fired power plants
  - High acid dew point temperature
  - Increased air heater deposits
  - NH_3 in effluent discharge
  - Potential for visible (“blue”) SO_3 plume

Formation and Fate of Ammonia

- Formation
  - Catalyst life – up to 20,000 hours
  - <1 ppm NH_3 for first half of catalyst life
  - ~2 ppm NH_3 at end of catalyst life
- Fate – removal of NH_3 slip
  - Air heater deposits – reaction of NH_3 and SO_3 to form ammonia bisulfate (ABS)
  - Ad/absorbed on fly ash
  - Absorbed in flue gas desulfurization (FGD) slurry
- Impact
  - Increased air heater deposits – ABS and fly ash
  - NH_3 in fly ash/FGD effluent discharge

Formation and Fate of Ammonia (Cont'd)

- Few reports on distribution of NH_3 slip
  - Some of air heater deposits recycled back to boiler as NOx - Ljunstroms
  - Best estimate - 50 to 80 percent on fly ash

Formation and Fate of SO_3

- Formation
  - Boiler SO_3 – 0.5 percent to 1.5 percent of SO_2
  - SCR SO_3 - ~1 percent of SO_2 (SCR ~doubles SO_3)
- Fate – removal of SO_3 (“inherent removal”)
  - Condensate on air heater surfaces
  - Air heater ash and ABS deposits
  - Electrostatic precipitator (ESP) fly ash
  - FGD slurry
- Impact of increased SO_3
  - Higher acid dew point temperature
  - Increased air heater deposits – fly ash and ABS
  - Potential for visible plume

Formation and Fate of SO3 (cont'd)

- Inherent SO3 Removal

- With increased SO3 from SCR, does percent removal or total ppm removed remain constant ?

- Boiler SO3: 20 ppm with 50% "inherent" removal = 10 ppm at stack

- Boiler + SCR SO3 = 20 + 20 = 40 ppm

with 50% "inherent" removal = 20 ppm at stack

with "constant" 10 ppm removed = 30 ppm at stack

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Air Heater Deposits

- General
  - Ammonia bisulfate (ABS) is primary product from reaction of NH_3 and SO_3
  - ABS condenses (initial formation temperature) at ~350°F and is “sticky”
  - IFT is a function of SO3 and NH3 – higher SO3 and NH3 → higher IFT
- Thermodynamic and kinetic analysis
  - High SO_3 : NH_3 ratio → high driving force for reaction and shorter temperature drop for completion of reaction
  - Turbulent gas flow results in condensation of ABS on cooler heat transfer surfaces
  - Laminar gas flow may produce ABS aerosol formation, which may pass through air heater (Results from rapid gas cooling before ABS diffuses to cooler air heater surfaces and condenses)

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Air Heater Deposits (Cont'd)

- Radian Equation
  - SO_3 ppm x NH_3 ppm x [T (IFT) – T (Rep)] where "T(Rep)" is a combination of exit gas temperature and cold end metal temperature
  - For 3.0 percent sulfur coal and 2 ppm NH_3 Slip – ABS deposits should form in air heater
  - SNCR appears to have deposits at a lower Radian number, probably due to uneven distribution of NH3 slip
  - Localized area of high NH3 slip may form a ring of ABS deposits in air heater, as baskets rotate past the high NH3 slip

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Ammonia in Effluent Discharge

- General
  - NH_3 is ad/absorbed on fly ash and in FGD slurry
  - NH_3 is soluble
  - NH_3 eventually ends up in effluent discharge
- Air heater wash water
  - Worst case - for 2 ppm NH_3 slip and all NH_3 in air heater, ~6,000 ppm NH_3 in wash water
  - Early operation – for 0.5 ppm NH_3 slip and 20 percent NH_3 in air heater, ~125 ppm NH_3 wash water
- Fly ash sluice pond discharge
  - Worst case – for 2 ppm NH_3 slip and 100 percent on fly ash, ~1.5 to 2.0 ppm NH_3 in fly ash sluice water
  - Early operation – for 0.5 ppm NH_3 slip and 70 percent on fly ash, <0.5 ppm NH_3

Ammonia in Effluent Discharge (Cont'd)

- FGD blowdown
  - Worst case – for 2 ppm NH_3 slip and 100 percent in FGD slurry, ~10 ppm NH_3 in FGD slurry (open loop operation)
  - Early operation – for 0.5 ppm NH_3 slip and 10 percent in FGD slurry, ~1 ppm NH_3
- Typical application – for 2 ppm NH_3 slip
  - Air heater – 20 percent and 1200 ppm
  - Fly ash – 70 percent and ~1 ppm
  - FGD – 10 percent and ~1 ppm
  - Composite – 1.2 ppm (average annual basis)

Ammonia in Effluent Discharge (Cont'd)

- Summary
  - Air heater wash water will have a "slug" of NH_3 to chemical treatment pond
  - Fly ash pond effluent discharge with air heater wash water blending (for each ppm of NH3 slip):

5 days	7 ppm NH_3
10 days	3.5 ppm NH_3
30 days	1.5 ppm NH_3

SO_3 Mitigation

- SO_3 removal location
  - In-furnace – >2500°F and ~2000°F
  - In-ductwork – ~650°F and 300°F
- Alkali for reaction
  - Limestone – either calcitic or dolomitic
  - Quick and hydrated lime - slurry or dry
  - Magnesium hydroxide – commercial and byproduct from Thiosorbic lime FGD
- In-furnace
  - >2500°F – dead burning, furnace slagging and high stoich
  - ~2000°F – using $Mg(OH)_2$
- In-ductwork
  - ~650°F – no published data
  - ~300°F – EPRI's High Sulfur Test Center

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SO3 Mitigation (cont'd)

- Each 1.0 alkali stoichiometry is approximately equal to 1% of the coal's ash (for high sulfur coals)

Balancing Ammonia Slip and SO_3

- Air heater
  - Optimize air heater cleaning cycle for ABS and fly ash deposits and for pressure drop – function of SO_3 at air heater inlet
- NH_3 in effluent discharge
  - Minimize steady-state NH_3 in effluent discharge: Optimum air heater deposits and treatment of air heater wash water – may eliminate need for SO_3 removal
  - If no limit on steady-state NH_3 in effluent discharge: No air heater ABS deposits, where SO_3 removal should be required

Conclusions

- SO3 removal system after SCR & before the air heater will:
  - Eliminate the potential for a visible SO3 plume and eliminate corrosion from higher acid dew point
  - Allow for balancing the NH3 deposition between the air heater and the ESP to minimize impact on plant operation

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Recommendations

- SO_3 measurements
  - Before and during SCR operation – determine where SO_3 is formed and removed
  - During SCR operation – determine whether percent removal or ppm removed is constant with increased SO_3
- NH_3 measurements
  - Wash air heater after first ozone season and collect wash water samples to estimate NH_3 in air heater. Monitor NH3 slip (at SCR outlet) and NH3 in fly ash → determines NH3 slip distribution
  - After first ozone season, increase NOx removal to increase NH_3 slip – to point where deposits are formed in air heater to determine plant specific Radian number

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